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DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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MILLING PRACTICE AT THE NETTA MINE OF THE EAGLE PICHER LEAD CO., AT PICHER, OKLAHOMA

BY

FRANK W. SANSOM

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MILLING PRACTICE AT THE NETTA MINE OF THE EAGLE PICHER LEAD CO. AT PICHER, OKLA.[1]

By Frank W. Sansom[2]

INTRODUCTION

This paper is one of a series of articles dealing with milling methods and costs at metal mines in the United States, written in accordance with an outline prepared by engineers of the United States Bureau of Mines and published by the bureau.

The Netta mine and concentrator is the largest of the plants of the Eagle-Picher Lead Co. It is located in Ottawa County, in the extreme northeast corner of Oklahoma, and in what is known as the Tri-State zinc and lead mining district, embracing the northeast corner of Oklahoma, the southwest corner of Missouri, and the southeast corner of Kansas. A majority of the production comes from the Oklahoma section, with Kansas second, and Missouri third.

The district is subdivided into camps or areas named after the small towns or communities that sprang up with the surrounding development. The Netta plant is in the Picher area; in fact, much of the mine workings are directly under the business section of Picher.

The ore horizon lies between 200 and 275 feet in depth, with the main working level at 275 feet.

The lease comprises 130 acres, upon which there are 8 shafts. Only two of these are now used, one a hoisting shaft equipped with balanced skips of 2½ tons capacity and a steel headframe. The man-hoisting shaft is equipped with one double-deck cage, counter balanced, having a capacity of 20 men.

The mill has a potential capacity of 120 tons per hour, but is now handling about 60 tons per hour.

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1 The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U. S. Bureau of Mines Information Circular 6342."

2 One of the consulting engineers, U. S. Bureau of Mines, and mill engineer of the Eagle-Picher Lead Co.

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ORE TREATED

The ores recovered are lead and zinc; lead in the form of lead sulphide or galena, the zinc in the form of zinc sulphide or sphalerite, locally known as blende or jack. The ore as it comes from the mine is known as rock or dirt and in this paper will be called dirt. The percentage of lead in the dirt varies from 1 to 5 per cent galena, and the zinc varies from 3 to 10 per cent blende.

The gangue is principally flint or chert with some limestone. Considerable black flint or jasperoid is usually present.

Iron pyrites is usually present closely associated with the ore minerals, and is the most troublesome mineral in concentration since its specific gravity is so nearly that of the blende. Chalcopyrite is occasionally found and calcite is also fairly plentiful. A few other minerals are found but these are the principal gangue materials.

The galena and blende occur principally in large crystals attached to the gangue, but are also found finely disseminated in the flint and black rock. In comparison with other complex ores, ours would be called free-milling, but the considerable amount of disseminated ore makes fine grinding necessary to secure a high percentage of recovery. This is especially true of the blende, which is not completely freed even at 35 mesh.

The flint and jasperoid gangue are very hard, brittle, and abrasive, which makes crushing and grinding costs high. The ore minerals are soft and easily ground.

BRIEF HISTORY OF CONCENTRATOR OPERATIONS

Milling methods in the Tri-State district are fairly uniform in general character, but each mill varies slightly in type or make of equipment and arrangement of the units. The nature and size of ore deposits and the size and terms of the leases have heretofore made large operations and the erection of large mills impracticable. There are a few mills of about 100 tons per hour capacity, but most of them handle only 50 or 60 tons per hour. The majority of the mills range in capacity from 300 to 500 tons per 10-hour shift.

One thing to be remembered in considering operations in this district is that practically all the mills operate only a single 10-hour shift per day - 8 hours underground. It has never been the practice to operate a continuous 24-hour day, as in many other mining districts. It appears, therefore, that our mills are very small in capacity, but if our Netta mine were operated to capacity for 24 hours a day it would handle 2,880 tons of rock per day or 850,000 to 1,000,000 tons per year. This would compare quite favorably with capacity of operations in other districts.

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There is a growing tendency to enlarge the scope of operations in this district. In fact the Netta mill was built originally upon a 40-acre lease, whereas the lease now consists of 130 acres.

The mills of this district have made greater progress in efficiency of operations in the last three or four years than in the previous 20 years. This improvement began with the successful application of flotation to our ores. Flotation had been on trial since about 1916 but was not immediately successful and many plants were discarded. The introduction of the Butchart flotation machines and the American continuous filter, together with improvement in oils and reagents, marked the beginning of successful flotation in this district.

Prior to 1917 very little effort was made to recover slimes. Slime concentrating tables were in use but they recovered only the coarsest and heaviest of the slimes and their production was very small. With the success of flotation came the need for fine grinding and thickeners. Steel-shelled rolls became more common, and ball mills and Dorr thickeners came into use. There was no particular need for these prior to this time as the slimes could not be recovered.

The proportion of zinc recovered by flotation now amounts to 20 to 25 per cent of the total production. This does not mean that zinc production was increased as much as this by the flotation system, since a considerable amount of slimes was recovered by jigs and tables. The installation of the desliming apparatus has resulted in practically all of the slimes being sent to thickeners and thence to the flotation plant.

Tests made by the U. S. Bureau of Mines have determined that with our disseminated ores, the mineral is not completely freed from the gangue until ground to minus 35 mesh. This necessitates the careful segregation of middlings of all sizes and their treatment in ball mills to secure a high recovery, especially of the zinc.

GENERAL FLOW SHEET OF MILL

The flow sheet (fig. 1) covers the operation of the entire mill, including crushing, handling, gravity concentration, and flotation. This flow sheet has recently been changed in the flotation department by the replacement of the lead froth concentrating table by a Butchart flotation machine and an American filter. This change is shown in the flow sheet of the flotation plant (fig. 4).

CRUSHING AND GRINDING

Breaking.- The mill rock is sized underground through a grizzly made of old railroad rails spaced 10 inches apart.

The breakers are 24-inch Webb City and Carterville boulder crushers, 24 by 12 inches, and of the Blake type.

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The breaker rolls are Webb City 42-inch Cornish-type rolls.

Each of the two sets of crushers and rolls have a capacity of 60 tons per hour. They are driven by belt drive, as is all other machinery throughout the mill.

Intermediate Crushing.- The regrind or return rolls, four in number, are Webb City 36-inch Blake-type rolls, in return circuit with two 4 by 5 by ½ foot vibrating screens.

The bed middlings from the chat jig, the hutch product from the last two cells, together with the tailings from the cleaner jig are reground on a set of 36-inch high-speed rolls (steel shells) in close circuit with a 4 by 6 foot by 2 millimeter vibrating screen. All crusher jaws and roll shells are of white iron or hard iron, made in local foundries, with the exception of the high-speed rolls above mentioned.

Primary Grinding.- All fine grinding is done in a 6-foot Cole ball mill. It is belt driven by a 50-hp. motor at a speed of 20 r.p.m. The mill is loaded with about 15 tons of 3-inch forged steel balls weighing about 4 pounds each. The average ball consumption is about 112 pounds of balls per 10-hour shift.

The liners are of manganese steel, but no record of their life has yet been obtained. It is estimated from their wear to date that they will be good for over 4,000 hours of service.

The ball consumption is about 2.2 pounds per ton of material ground.

The following table gives a screen analysis of ball-mill products:

Screen analysis of ball-mill products

Size	ZnS content in blende, per cent	Per cent of size	Calculated per cent of blende	Per cent of blende, value
BALL MILL FEED				
Plus 20 mesh	23.75	31.16	7.40	45.84
Minus 20 Plus 35 mesh	12.00	34.75	4.17	25.83
Minus 35 Plus 65 mesh	11.75	30.44	3.58	22.16
Minus 65 mesh	27.30	3.65	0.99	6.17
		100.00	16.14	100.00
BALL MILL DISCHARGE				
Plus 20 mesh	11.50	4.44	0.51	3.20
Minus 20 Plus 35 mesh	10.50	19.96	2.10	13.15
Minus 35 Plus 65 mesh	11.40	34.93	3.98	24.96
Minus 65 mesh	23.00	40.67	9.35	58.67

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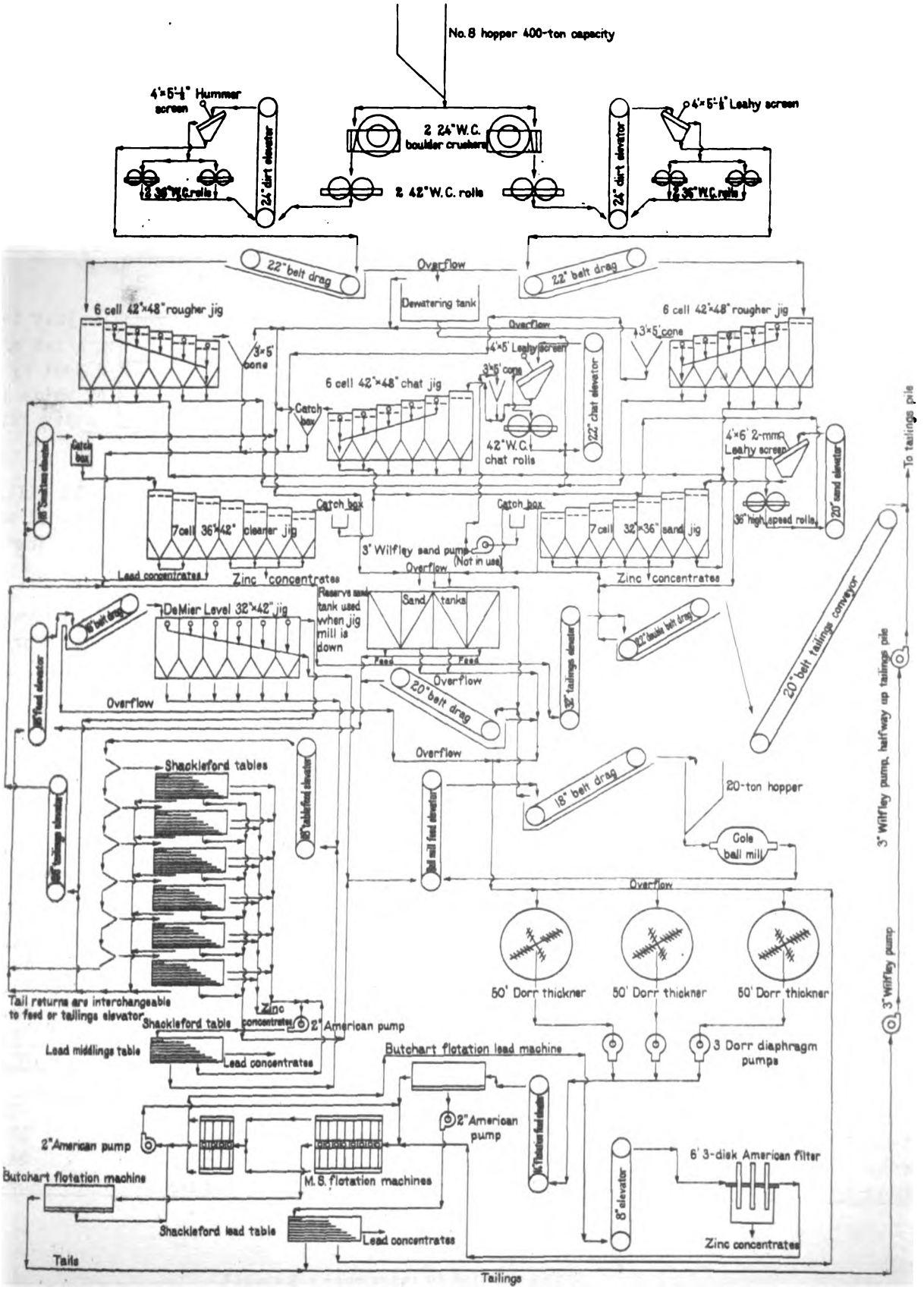

FIGURE 1.— Flow sheet of Netta mill

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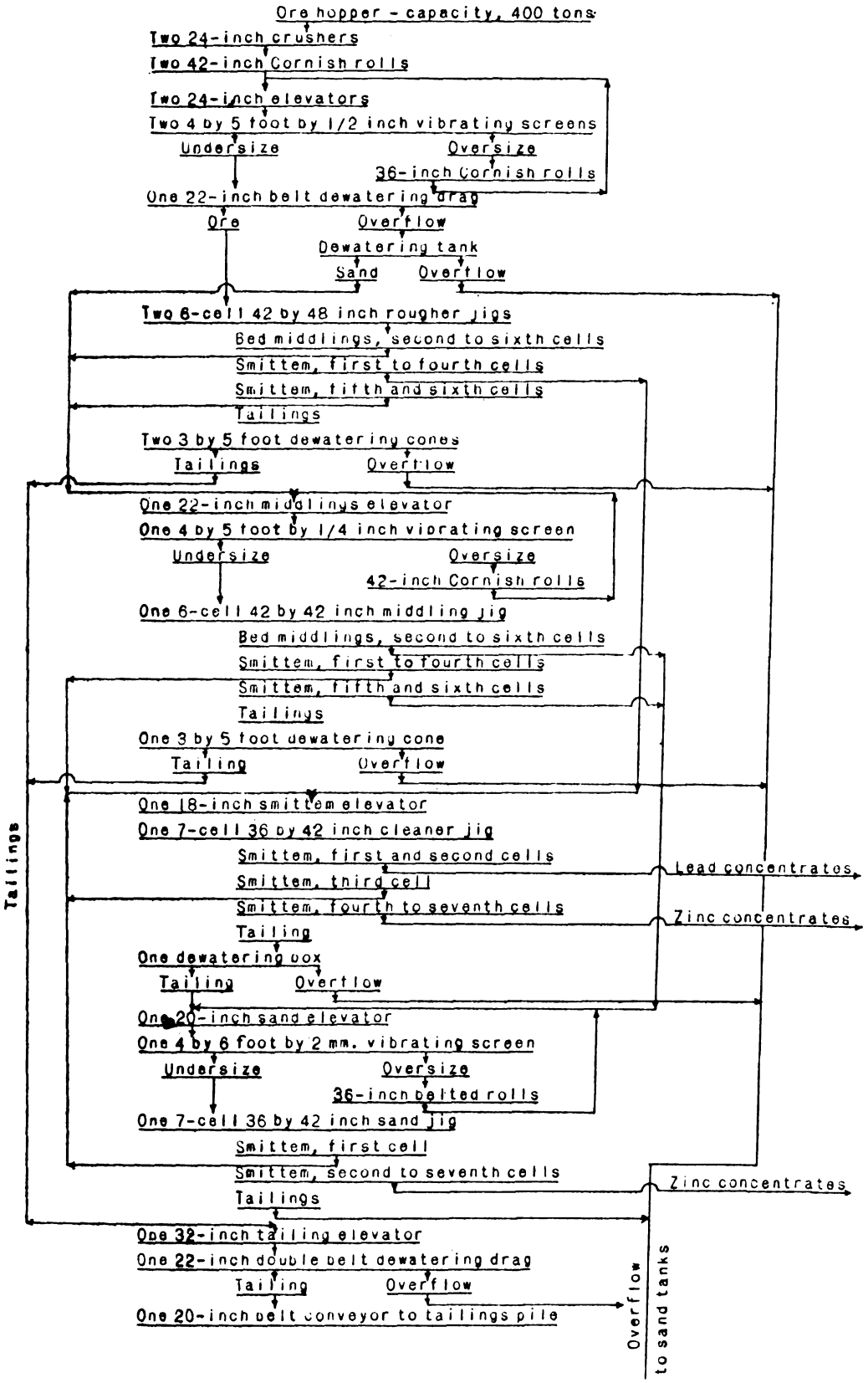

Figure 2.- Flow sheet of Netta jig mill

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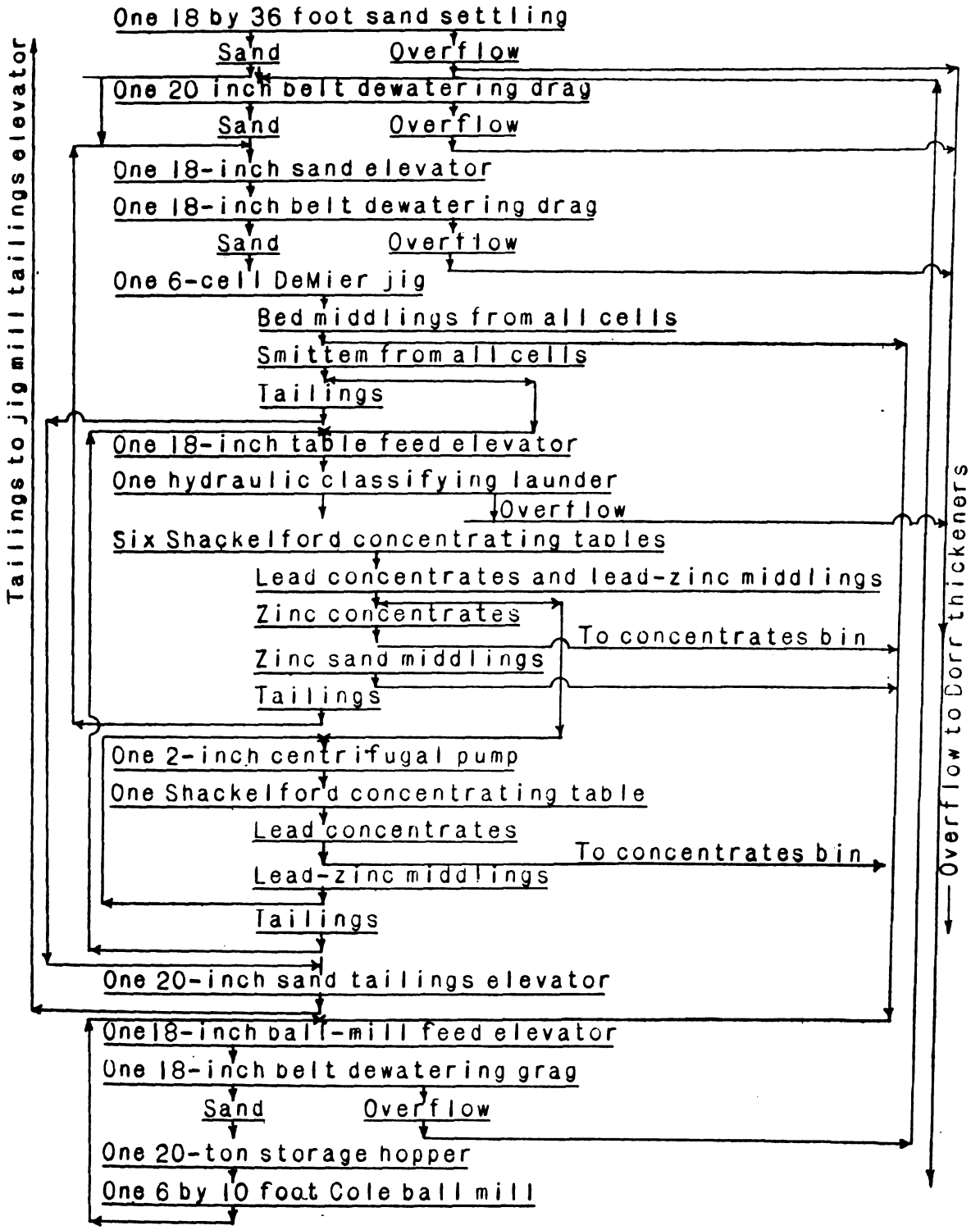

Figure 3.- Flow sheet of sludge mill

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SCREENING AND CLASSIFICATION

All screening is done with vibrating screens, as follows:

1 4' x 5' x ½" Hummer dirt screen
1 4' x 5' x ⅜" Leahy dirt screen
1 4' x 5' x ¼" Leahy chat screen
1 4' x 6' x 2 mm. Leahy sand screen

The classification consists principally in desliming, which is done with desliming drags and cones. Belt drags are installed ahead of the rougher jigs. These not only deslime the feed but also provide a dry feed to the jigs, eliminating the usual excess of water in the feed. This allows the introduction of more water on the plungers where it is most needed and has proved beneficial to the efficiency of the jigs.

A 3 by 5 foot DeMier dewatering cone at the tailings end of each rougher serves to further deslime the rougher tailings, as well as to relieve the tailings elevator of a large amount of excess water.

The jig tailings are again deslimed by a belt drag, the main purpose of which is to dewater the tailings before loading onto the tailings belt conveyor.

All the overflow water from these drags and cones now goes to the sludge mill where it is again deslimed in a large belt drag. The deslimed sand is elevated into another belt drag which feeds the DeMier jig in the sludge mill.

The overflow from these last two drags goes to the Dorr thickeners, and is the source of feed for the flotation plant. Another belt drag deslimes the feed to the ball mill, the overflow returning to the sludge mill drag.

These drags and cones make a complete desliming at all stages of concentration and permit very few slimes to escape with the tailings.

GRAVITY CONCENTRATION

The flow sheet of the jig mill (fig. 2) includes the crushing and grinding department. This section concentrates at three different sizes, the rougher jig at minus ½ inch, the chat jig at minus ¼ inch, and the sand jig at minus 2 millimeter.

The cleaner jig treats the smittem from the two roughers, the chat jig and the first hutch from the sand jig.

The equipment from the crushers down to the rough jigs is arranged in duplicate units. The crushers, dirt rolls, dirt elevators, dirt screens, return rolls, return elevators, and dewatering drags are driven by a 100 hp. motor on each unit so that each of the two units may be operated separately. In this way each unit down to this point may be stopped without interfering with the other and the balance of the jig mill.

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The flow sheet then is as follows:

The dirt from the crusher goes by gravity to the dirt rolls, thence to a 24-inch dirt elevator, where it is elevated to the vibrating screens. The oversize goes by gravity to the return or regrind rolls, thence by the return elevator back to the screen, reducing the feed to 2-inch size for jigging.

The undersize from the dirt screen goes by gravity to a 22-inch belt dewatering drag and is discharged directly onto the rougher jig. The overflow from the drag usually contains coarser material than advisable to send to the sludge mill, so it is again dewatered in a dewatering tank, from which the coarser material is drawn off and goes to the chat or middlings jig.

Rougher Jigs; 6 cells, 42 by 48 inches.- The rougher jig is equipped with "chatters," a device for drawing off chats from the beds. Chats are drawn from the second, third, fourth, fifth, and sixth cells, and together with the smittem or hutch product from the fifth and sixth cells go to the middlings elevator.

The smittem from the first 4 cells goes to the smittem elevator and to the cleaner jig.

The rougher tailings are dewatered in a 3 by 5 foot cone and thence go to the tailings elevator.

Coarse middlings.- The middlings product from the middlings elevator go to a 4 by 5 foot by ¼ inch vibrating screen, the oversize going to a set of 42-inch chat rolls and back to the middlings elevator; the undersize goes by gravity to the middlings jig.

Middlings jig; 6 cells, 42 by 48 inches.- The bed middlings from the second to the sixth cells are drawn as described above, and together with the hutch product from the fifth and sixth cells go to the sand elevator; all other hutch product goes to the smittem elevator.

The tailings are dewatered in a 3 by 5 foot cone and go to the tailings elevator.

Cleaner Jig; 7 cell, 36 by 42 inches.- The feed for the cleaner jig is derived from the smittem from the rougher and chat jigs as above described.

The smittem from the first and second cells is a lead concentrate. The coarse lead on the beds of these two cells as it accumulates is shoveled off by hand and added to the smittem lead.

The third hutch is called an "idler cell"; the smittem being a mixture of lead and zinc and zinc-lead middlings, is returned to the smittem elevator for retreatment. Smittem from the fourth to seventh cells is a zinc concentrate. The cleaner tailings go to the sand elevator.

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Sand Jig; 7 cell, 36 by 42 inches.- The feed for the sand jig is derived, as above described, from the chat circuit and cleaner jig tailings, and is elevated by the sand elevator to a 3 by 6 foot by 2 millimeter vibrating screen.

The oversize is in closed circuit with a set of 36-inch high-speed rolls, the undersize going by gravity to the sand jig.

The smittem from the first cell of the sand jig is a mixture of lead and zinc and returns to the smittem elevator for retreatment on the cleaner jig. The smittem from all other cells is a zinc concentrate and is mixed with the zinc ore from the cleaner jig.

It is not necessary to draw bed middlings from this jig, as the tailings go to the sludge mill and all middlings products are treated there.

Screen analysis of rougher jig heads

Size	Blende content, per cent	Per cent of size	Calculated per cent	Per cent of zinc
Plus 3 mesh	1.27	23.07	0.293	6.90
-3 plus 8 mesh	2.70	43.83	1.183	27.85
-8 plus 35 mesh	5.50	22.14	1.218	28.65
-35 plus 65 mesh	9.95	4.22	0.420	9.88
-65 mesh	16.85	6.74	0.674	26.75
Total	- -	100.00	4.25	100.00

TAILINGS DISPOSAL

The tailings from the rougher jig, middlings jig, and from the sludge mill all go to a 32-inch tailings elevator, thence to a double 22-inch belt dewatering drag. This drag discharges the dewatered tailings directly on a 20-inch standard belt conveyor which elevates it to the tailings pile. Clear water is pumped to the head of the conveyor to facilitate distributing the tailings on the pile.

The tailings pile is surrounded by a dam and, the water is returned to the mill pond.

A local "chat company" has erected loading equipment near the pile and is now loading the tailings into railroad cars for ballast and other commercial uses.

FLOW SHEET OF SLUDGE MILL

The feed product for the sludge mill (fig. 3) coming from various dewatering devices in the jig mill, together with the sand jig tailings, is dewatered in a 20-inch belt drag.

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A flat settling tank 18 by 36 feet formerly used in collecting this sand feed is now used as an emergency tank when the sludge mill is temporarily shut down.

The sand product from this drag goes to an 18-inch feed elevator and to an 18-inch belt drag which again dewaters the sand as feed to the DeMier level jig. The overflow from both drags goes to the thickeners and is the sole source of flotation feed.

The DeMier level jig (6 cell, 32 by 42 inch) is built similarly to the standard jig except that all cells are at the same level; that is, they do not have the 2-inch drop from one cell to the next. To facilitate the travel of the material on the jig, a raking device, similar to that of the Dorr drag classifier, is suspended over the full length of the jig, with rakes about 18 inches apart. These rakes drag the surface of the bed intermittently forward toward the tail of the jig. This type of jig has proved very effective in jigging sand.

Bed middlings are drawn from all cells and go to the ball-mill feed elevator.

All hutch products go to the table feed elevator, and thence are sent through a hydraulic launder system to a battery of 6 Shackelford concentrating tables.

The tailings from this jig go to an 18-inch tailings elevator, thence to the jig mill tailings elevator, and to the tailings pile. The distribution of the products from the tables is as follows:

The zinc concentrates go to zinc concentrates bin to be mixed with jig mill zinc. The zinc-sand middlings to to the ball-mill feed elevator. Lead-zinc middlings go to another Shackelford table for recleaning. The tailings return to the DeMier jig, all tailings from the sludge mill being discarded by the DeMier jig.

The products from the lead recleaning table are disposed of as follows: The lead concentrates go to be mixed with the jig lead in the storage bins. The lead-zinc middlings return again to the lead table circuit. The zinc and table tails return to the main table circuit.

The purpose of this lead recleaner may need explanation. When the feed to the tables is lean in lead, the ribbon of lead concentrates on the table is so narrow (only an inch or so) that it is difficult to make an accurate separation of lead and zinc. By combining this middlings product from the six tables, a feed rich in lead is furnished to the middlings table which is then ribboned in lead from 10 to 15 in. wide, and a clean lead concentrate is easily made.

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THE BALL MILL

The ball-mill feed consists of the bed middlings from the DeMier sand jig and the zinc-sand middlings from all the concentrating tables. This feed is elevated by the 18-inch ball-mill feed elevator into an 18-inch belt dewatering drag, where it is dewatered into a 20-ton storage hopper. The overflow is returned to the 20-inch belt drag feeding the sludge mill.

The feed is drawn from the hopper into the ball mill with enough clear water added to regulate the pump density.

The ball-mill discharge is returned to the ball-mill feed elevator and is thus in closed circuit with the dewatering drag. It has not proved advisable to send the overflow from this drag direct to the thickeners, as it contains too much coarse product. It is returned to the sludge-mill feed drag at the head of the sludge mill.

Screen analysis of sludge mill feed

Size	Blende content, per cent	Per cent of size	Calculated per cent	Per cent of zinc
Plus 10 mesh ---------	4.05	31.71	1.28	23.03
Minus 10 plus 65 mesh-	3.75	58.18	2.22	39.80
Minus 65 mesh --------	22.75	9.11	2.07	37.17

FLOW SHEET OF FLOTATION PLANT

The slime product for the flotation plant (fig. 4) comes from the various desliming drags and cones as described under gravity concentration, but comes direct to the thickeners only from the two drags at the head of the sludge mill.

These slimes are then collected in three 50-foot Dorr thickeners, the thickened pulp drawn off by three Gould-diaphragm pumps into a 14-inch flotation feed elevator. The feed goes to Butchart lead rougher machine No. 1. The tails from this machine go to zinc rougher No. 3, the froth to lead cleaner No. 2, The tails from the lead cleaner return to the lead rougher, the froth to a 1½-inch centrifugal pump then to a 6-foot 2-disk American filter. The filtrate, a lead concentrate, goes to the lead storage bins.

The tails from zinc rougher No. 3 go to a zinc scavenger machine No. 5, the froth to zinc cleaner machine No. 4. The froth from the zinc cleaner goes to a 6-foot 3-disk American filter, the tails returning to zinc rougher No. 3.

The tails from zinc scavenger No. 5 go to two 3-inch Wilfley slime pumps in tandum, the second pump located about halfway up the tailing pile, pumps the slimes to the top of the main tailings conveyor to be used as wash water to distribute the tailings to the pile.

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The filtrate from the zinc filter is a zinc concentrate and goes to the flotation zinc storage bins, the filter overflow returning to the zinc rougher No. 3.

Screen analysis of flotation feed

Size	Per cent of size
Plus 48 mesh	2.51
Minus 48 plus 65 mesh	8.21
Minus 65 plus 100 mesh	16.15
Minus 100 plus 200 mesh	35.37
Minus 200 mesh	37.76
	100.00

Screen analysis of flotation zinc concentrates

Size	Per cent of size
Plus 35 mesh	.038
Minus 35 plus 48 mesh	.499
Minus 48 plus 65 mesh	2.346
Minus 65 plus 100 mesh	7.790
Minus 100 plus 200 mesh	52.449
Minus 200 mesh	36.878
Total	100.000

Flotation reagents per ton of zinc concentrates

	Pounds per ton	Cost per ton
Copper sulphate	8.36	$0.573
Cresylic acid	2.63	0.248
Sodium xanthate	2.22	0.333
Sodium silicate	.67	0.015
Total cost per ton -		$1.169

CONVEYING

The Netta mill, like all mills in the Tri-State district, is built on level ground, so that with few exceptions the material must be elevated from one machine to the next. This is done by cup elevators.

All launders are made of wood. When handling coarse material they are lined with hard iron spouting in 3-foot lengths. When conveying sand they are lined with sheet steel in various lengths.

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The only belt conveyor in the mill is the tailings conveyor, which is a standard belt conveyor with troughing rollers using a 20-inch belt. The conveyor is lengthened when necessary and is now about 200 feet long. The tailings are distributed on the pile by sheet steel launders laid along on the pile.

METHOD OF HANDLING CONCENTRATES

Jig concentrates are shoveled from the jig boxes into a steel dump car on a 22-inch gage track and pushed by hand to the storage bins. The jig ore cars have a capacity of 1,000 pounds zinc and 2,000 pounds lead. The table concentrates are handled in the same way in cars holding 500 pounds of zinc and 1,000 pounds of lead. The filtered flotation concentrates are drawn into the cars by gravity, the cars having a capacity of 900 pounds zinc and 2,000 pounds lead.

The filtered concentrates have a moisture content of about 10 per cent.

DEWATERING AND DISPOSAL OF TAILINGS

The dewatering is done by a belt drag, as described elsewhere. The tailings disposal in this district is sometimes quite a problem, especially where the leases are only 20 or 40 acres in size. There must, therefore, be piles as high and as dry as possible so as to occupy the least room possible. The tailings piles are always surrounded by earthen dams which impound the seepage, and by proper ditching the seepage is conducted back to the mill water storage pond.

The majority of the water used in milling goes to the Dorr thickeners, the overflow going to the mill pond.

So far very little or no trouble has been experienced in this district from pollution of streams. The pollution in small tributary streams is no doubt considerable, but it seems to be pretty well dissipated by the time it reaches the rivers and does no harm.

SAMPLING

The three tailings products, jig tails, sand tails, and flotation tails, are sampled twice daily. This is done by an employee of the metallurgical department, who visits each mill twice daily at irregular intervals. These samples are kept in the mill in a locked container and are collected once a week. They are then quartered down and assayed, usually only for blende. Lead and zinc concentrates are similarly sampled and assayed for lead (Pb), zinc (Zn), iron (Fe), and lime (CaO).

The weekly assay results are tabulated and typewritten on cards, and these cards are posted in all departments of each mill and in all offices.

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While this method of sampling is crude and simple, it is very effective and that tends to hold the tailings losses and ore grades at a very fair average. About its only virtue is that it shows the mill operators what their tailing losses are and gives a direct comparison of results with each department in all of the company's mills. Of course, special sampling is continuously going on to correct losses and check efficiencies of machines and flotation reagents, and occasionally each mill is sampled thoroughly to determine its efficiency.

Tailing assays from 1927 to March, 1930

All assays in metallic zinc

Year	Jig tails, per cent	Sand tails, per cent	Flotation tails, per cent	Composite tails, per cent
1927	0.96	1.39	0.95	1.05
1928	0.68	0.94	0.64	0.72
1929	0.85	1.11	0.60	0.88
1930	0.66	0.82	0.70	0.69

Grade of zinc concentrates for 1928-29-30

Year	Zn, per cent	Fe, per cent	Pb, per cent	CaO, per cent
JIG AND TABLE ZINC MIXED				
1928	58.82	- -	1.99	0.81
1929	58.58	2.07	1.64	0.89
1930	59.12	1.97	1.97	1.04
FLOTATION ZINC				
1928	60.66	- -	1.52	0.56
1929	61.61	1.36	1.27	1.22
1930	59.72	2.02	1.90	0.93

The last sample taken to determine mill efficiency showed a percentage of extraction for the entire mill of 86.23 per cent of the lead and zinc.

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POWER

The power equipment is entirely electric, and the different units are driven as follows:

2 100-hp., driving crushers, dirt rolls, dirt elevators, dirt screens, return rolls, return elevators, and dewatering drags.

1 150-hp., driving jigs, chat, sand, and smittem elevators, chat and sand tolls, chat and sand screens.

1 25-hp., driving mill pump.

1 15-hp., driving triplex pump.

1 25-hp., driving tailings elevator.

1 15-hp., driving tailings dewatering drag.

1 20-hp., driving tailings conveyor.

1 35-hp., driving sludge mill.

1 7½-hp., driving sludge-mill tailings elevator.

1 50-hp., driving ball mill, ball-mill elevator and drag.

1 50-hp., driving part of flotation plant.

1 35-hp., driving part of flotation plant.

1 20-hp., driving flotation tailings pumps.

Total number of motors: 14.

Total horsepower: 6,475.

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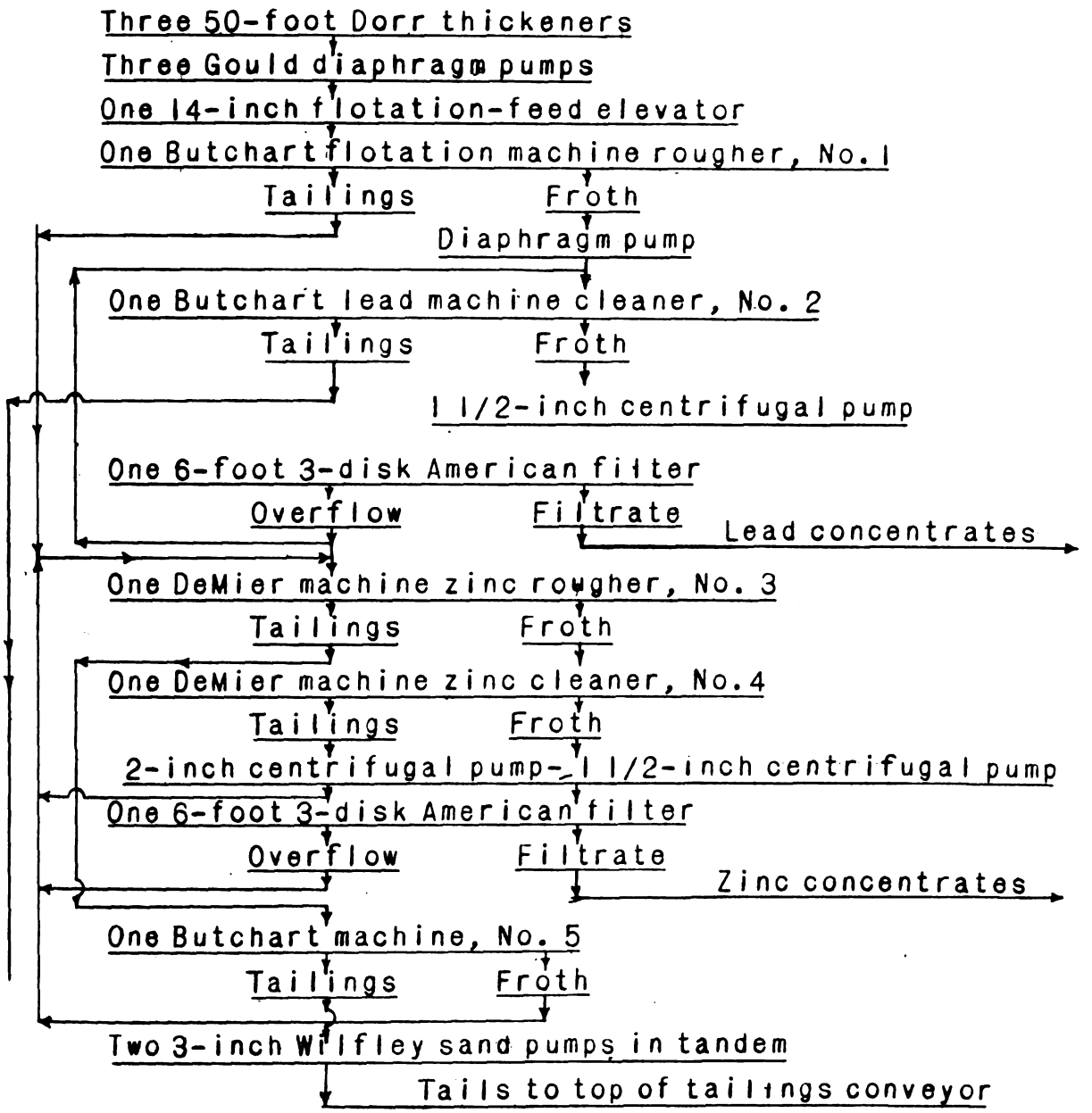

Figure 4.- Flow sheet of flotation plant

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